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DESCRIPTION

TRANSFORMER

TECHNICAL FIELD

The present invention is directed to a transformer which gives a high pulse voltage required in a starting device for a high intensity discharge lamp.

BACKGROUND ART

Such transformer is known from Japanese Patent Publication No.2002-217050 and No, 2002-93635 to include an inner winding placed directly around a bar-shaped ferrite core, an outer winding wound over the inner winding, and a dielectric shield surrounding the windings. The dielectric shield is formed by an injection molding and is made of unsaturated polyester which is a thermosetting dielectric resin and is mixed with a filler enhancing heat-resistance as well as impact-strength.

In the transformer, the outer winding is wound along substantially the full length thereof in a closely relation to the inner winging. In this condition, there appears a substantially closed space within one turn of the outer winding around the inner winding. The substantially closed space is a space into which the dielectric molding resin including the filler is difficult to flow during the injection molding, and therefore remains as a void after forming the dielectric shield. As a result of that the void free from the resin remains, the transformer suffers from a lowered dielectric strength and therefore fails to give an intended voltage difference between the outer and inner windings over a long period of use. For example, in case 800 volts are applied to the outer winding of 5 turns with the inner winding of 200 turns, there is developed a 10 to 20 kV across the inner

windings. In the presence of the void between the outer and inner windings, the voltage of 10 to 20 kV is likely to develop a corona discharge responsible for an aged deterioration of the dielectric strength which eventually causes a discharge between the outer and inner windings, thereby failing to give the intended high voltage from the inner winding.

DISCLOSURE OF THE INVENTION

In view of the above insufficiency, the present invention is accomplished to provide a transformer which is capable of restraining the void in a dielectric shield forming a shell of the transformer to give a reliable performance over a long life.

The transformer in accordance with the present invention includes a bar-shaped ferrite core, an inner winding placed around the ferrite core, an outer winding wound over the inner winding, and a dielectric shield surrounding the outer winding. The inner winding is an electrically insulated flat wire having a rectangular cross section and is wounded intimately around the ferrite core with a length of the rectangular cross section extending perpendicular to an axis of the ferrite core. The outer winding has its circumference covered by a dielectric sheath, and has an intermediate winding portion between its winding start end and its winding stop end. The present invention features that the dielectric sheath in the intermediate winding portion is spaced from each other along the axis of the ferrite core to leave a gap thereat, the gap being filled with a molding material. By provision of the gap between the dielectric sheath of the outer winding, the molding material forming the dielectric shield can be easy to flow in between the dielectric sheath of the outer winding and the inner winding, avoiding the void from appearing between the inner and outer windings for attaining stable

electrical characteristic.

It is preferred that one turn of the outer winding is spaced along the axis of the ferrite core from the adjacent turns of the outer winding by a distance of 10 μm or more within the intermediate winding portion.

Preferably, each of the winding start end and the winding stop end includes two or more close turns of the outer winding. When the dielectric sheath is of a self-adhesive nature, this arrangement enables to prevent a spring-back unwinding both at the winding start and stop ends prior to molding the dielectric shield. Although the outer winding is wound closely at these ends, the gap is formed in the intermediate winding portion where the outer winding is would loosely is wound loosely so as to allow the molding material to flow from the gap into the closely wound portion, thereby preventing the void from remaining in the winding start and stop ends.

Also, it is preferred that the outer winding is secured on the inner winding by means of an adhesive layer formed on the inner winding for avoiding the spring-back unwinding of the outer winding. A heat-sealing agent can be applied as the adhesive layer.

Further, the outer winding may be secured to the inner winding by means of a heat-sealing layer covering at least one of the outer winding and the inner winding for avoiding the spring-back unwinding of the outer winding..

One turn of the outer winding may have its portion spaced outwardly from the periphery of the inner winding. In this instance, a large open space can be formed between the inner and outer windings so as to be closely packed by the molding material for avoiding the void.

Further, a dielectric spacer may be disposed around the circumference of the

inner winding in order to space the outer winding from the inner winding, thereby forming a like large open space between the inner and outer windings to be closely packed with the molding material and preventing the occurrence of the void. In this instance, the dielectric space can be best utilized to have a guide groove which determines the winding direction of the outer winding for facilitating the winding operation of the outer winding. Also, the dielectric space may be provided with a means for retaining the ends of the inner winding around the ferrite core in order to prevent the unwinding of the inner winding by use of the dielectric spacer.

The present application also discloses various advantageous structures with regard to a fixture which is responsible for securing the ends of the inner winding around the ferrite core. The fixture is attached to the ferrite core to retain the ends of the inner winding to predefined portions for avoiding the unintended unwinding.

The fixture is preferably prepared as a cap made of a dielectric resin. The cap is configured to have an opening larger than the end face of the ferrite core, a plurality of projections projecting from the periphery of the opening into the opening to come into abutment against the periphery of the end of the ferrite core for fixing the cap to the ferrite core.

The fixture may be shaped into a resilient plate and is formed around the opening with a slit so that is it given an elastic deformability to vary the size of the opening for facilitating the mounting of the cap on the end of the ferrite core.

The cap is preferably formed with a notch at which the ends of the outer winding are captured. Thus, the single cap can ensure to prevent the unwinding of the inner and outer windings. When the cap is configured to be embedded in

the dielectric shield, it can be utilized to position the ferrite core within a molding die used for realizing the dielectric shield, thereby enabling to give the dielectric shield accurately around the inner and outer windings.

The fixture may be configured to have a pair of caps and coupling arms coupling the caps. In this instance, the inner winding can be caught between the caps respectively disposed at the opposite axial ends of the ferrite core to thereby hold both of the winding start and stop ends to the destined positions around the ferrite core.

Preferably, the ferrite core has a cross-section surrounded by two parallel straight lines and two arcuate curves. The coupling arms extend in an axial direction of the ferrite core outside of the arcuate curves so as to give a reduce profile with regard to the height defined between the two straight lines. Further, the coupling arm may be formed with guide grooves which determine the winding direction of the outer winding for facilitating the winding operation of the outer winding. Also, the coupling arm may be formed with a notch which holds the ends of the outer winding for prevention of the unwinding of the outer winding prior to molding the dielectric shield.

Further, the coupling arm may be formed with terminal lugs around which the ends of the outer or inner winding are wound to be held thereat. Thus, the coupling arm can facilitate the connection of the winding to the terminal lugs for an external circuit.

The fixture can be fitted into grooves formed in the end of the ferrite core so as to be secured thereto, and is preferred to have a terminal lug holding the end of the inner winding. The fixture is preferably made of a magnetic material or an electrically conductive material.

Moreover, the fixture may be configured to have a retainer holding the end and a leg inserted between the ferrite core and the inner winding around the ferrite core. In this instance, the leg can be placed in a recess formed in the end of the ferrite core.

The leg may have an inclined surface which bears thereon the inner winding. The inclined surface is configured to give a radial distance from the periphery of the ferrite core which is greater towards the center of the ferrite core than at the one end of the core where the leg is attached. With this arrangement, the inner winding can hold the fixture firmly to the ferrite core so as to retain the fixture on the ferrite core even when the fixture is subject to an external force, during the molding of the dielectric shield, which would otherwise push the fixture away from the ferrite core along the axial direction thereof.

The fixture may be also provided with terminal lugs that hold the inner winding extending out from the periphery of the ferrite core. In this instance, the fixture can be made of a dielectric material, while the terminal lugs are attached to the fixture in an electrically insulating relation to the ferrite core.

Further, the fixture may be configured to have a plurality of legs which are inserted between the ferrite core and the inner winding at a plurality of spots around the end of the ferrite core.

As an alternative means for fixing the ends of the inner winding to the ferrite core, the ferrite core may be formed at a portion adjacent its axial end with notches. A flange is defined between the notch and the end face of the ferrite core such that the inner winding can have its end wound around the notches as being pressed against the flanges for fixing the end of the inner winding around the ferrite core. In this instance, it is preferred that the notch has a bottom of

which depth is greater towards the end face of the ferrite core in order to minimize a level difference appearing on the exterior of the inner winding adjacent the notch.

These and other objects and advantages will become apparent from the following description of the embodiments when taken in conjunction with the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view illustrating an appearance of a transformer in accordance with the present invention;

FIG. 2 is a perspective view of an internal structure of the above transformer;

FIG. 3 is a sectional view of the above transformer;

FIG. 4 is a partially enlarged sectional view of the above transformer;

FIGS. 5 and 6 are perspective views respectively illustrating the fabricating steps of the above transformer;

FIG. 7 is a partially enlarged sectional view of a modification of the above transformer;

FIGS. 8 and 9 are sectional views respectively illustrating modifications of the above transformer;

FIG. 10 is a perspective view of a dielectric spacer applicable to the above transformer;

FIG. 11 is a perspective view of another dielectric spacer applicable to the above transformer;

FIG. 12 is an exploded perspective view of a fixture which is utilized in a transformer in accordance with a second embodiment of the present invention;

FIG. 13 is an end view illustrating the fixture in its mounted position;

FIG. 14 is an exploded perspective view of a modification of the fixture utilized in the above transformer;

FIG. 15 is an exploded perspective view of another modification of the fixture utilized in the above transformer;

FIGS. 16, 17, and 18 are perspective views respectively of various modifications of the fixture utilized in the above transformer;

FIGS. 19 and 20 are perspective views respectively of other modifications of the fixture utilized in the above transformer;

FIG. 21 is a perspective view of a fixture utilized in a transformer in accordance with a third embodiment of the present invention;

FIG. 22 is a perspective view of the fixture in its mounted position;

FIGS. 23 and 24 are exploded perspective views respectively of other fixtures applicable to the above transformer;

FIG. 25 is a sectional view of the fixture in its mounted position;

FIG. 26 is a perspective view of another fixture;

FIGS. 27 and 28 are perspective views respectively of other fixtures applicable to the above transformer;

FIG. 29 is a sectional view of the above fixture in its mounted position;

FIG. 30 is a perspective view of a modification of the above fixture;

FIG. 31 is a perspective view of a ferrite core utilized in the above transformer;

FIG. 32 is a partial plan view of the above ferrite core;

FIG. 33 is a partial plan view of the ferrite core with a winding;

FIG. 34 is an end view of the ferrite core; and

FIG. 35 is an end view of another modification of the ferrite core.

BEST MODE FOR CARRYING OUT THE INVENTION

A transformer in accordance with the present invention is designed as an optimal pulse transformer for giving a staring voltage to a discharge lamp for use in a headlamp of a vehicle, and is configured to have a coil block **20** composed of a ferrite core **10** carrying two inner and outer windings **30** and **40**, as shown in FIG. 2, and a dielectric shield **50** surrounding the block as shown in FIG. 1.

The inner winding **30** is a so-called flat wire composed of a ribbon conductor covered by a dielectric sheath of a polyimide resin or the like, and is wound directly around the bar-shaped ferrite core **10** in an edgewise fashion. That is, as shown in FIGS. 3 and 4, the inner winding **30** is wound, for example, by 200 turns around the ferrite core **10** with a length of its section crossing with an axis of the ferrite core, and with the wires being close to each other, to constitute a secondary winding of the transformer for developing a high voltage across the ends of the inner winding.

The outer winding **40** is made of a general round conductor **41** covered by a dielectric sheath **42** of fluorine resin or the like, and is wound over the inner winding **30**, for example, by 5 turns to constitute a primary winding of the transformer. Upon receiving, for example, 800 V at the primary winding, the secondary winding develops the high voltage of 10 kV to 20 kV across the ends thereof.

The dielectric shield **50** is formed by an injection molding from a thermosetting resin such as unsaturated polyester including a filler so as to surround the coil block **20**. Input terminal lugs as well as output terminal lugs, which are provided respectively for connection with the ends of the outer and

inner windings **40** and **30**, are simultaneously molded into the dielectric shield **50** to be retained thereby.

As shown in FIGS. 2 to 4, the outer winding **40** has a winding start end **46** and a winding stop end **47**, and is wound over the inner winding **30** in such a manner that the start and stop ends **46** and **47** have their respective dielectric sheaths **42** spaced from each other to leave a gap **48** between the adjacent ones of the winding. The gap **48** has a gap length **L** of 10 μm or more along the axial direction of the ferrite core **10**. In the presence of the gap **48**, the injection molding of the dielectric shield **50** can be accompanied with a smooth resin flow in between the outer winding **40** and the inner winding **30**, thereby leaving no void which would be troublesome for the transformer operation, and therefore assuring a stable operation characteristic. In order to hold the outer winding **40** over the inner winding **30** prior to molding the dielectric shield **50**, the outer winding **40** is wound around the inner winding **30** through a tape **60** coated with an adhesive or a pressure-sensitive adhesive is placed over the inner winding.

The winding start and stop ends **46** and **47** are wound respectively by 1 to 2 turns with the respective dielectric sheathes **42** being held intimately to each other so that they are restrained from being unwound. With reduced number of turns, the resin can be forced to flow from the gap **48** into a space between the outer winding **40** and the inner winding **30** at the winding start and stop ends, thereby filling the space successfully with the resin. When the dielectric sheath **42** of the outer winding **40** is made of a fluorine resin having a self-adhesive characteristic, the unwinding at the start and stop ends can be prevented as well. It is noted that, as shown in FIG. 7, the winding start and stop ends may be each configured to have the gap **48**. Instead of using the tape **60**, the inner winding

may be coated with a heat-sensitive agent followed by being wound by the outer winding **40** at a heated atmosphere. It is also possible that at least one of the inner winding **30** and the outer winding **40** is configured to have the heat-sealing dielectric sheath in order to retain the outer winding **40** around the inner winding **30** prior to molding the dielectric shield **50**.

As shown in FIGS. 5 and 6, the dielectric shield **50** is molded by injection over the coil block **20** held in a conductor frame **70** to surround the coil block. The conductor frame **70** includes input terminal lugs **71** and **72**, as well as output terminal lugs **73** and **74**, all of which are molded in the dielectric shield **50** and are finally detached from the conductor frame **70**. Each of the terminal lugs **71** to **74** is formed to have a catch for connection with the end of the inner winding **30** and the outer winding **40**.

FIG. 8 illustrates a modification of the coil block **20** in which the outer winding **40** is wound in such a manner as to leave radially extending gaps **49** outwardly of the inner winding **30**. In detail, the inner winding **30** is wound around the ferrite core **10** having a cross-section surrounded by two parallel straight lines and two arcuate curves. The outer winding **40** is held close to straight portions of the inner winding **30**, while it is spaced away from the arcuately curved portions of the inner winding **30** to give the gaps between the two windings **30** and **40**.

FIG. 9 illustrates another modification of the coil block **20** in which the outer winding **40** is wound in a circular pattern as being in held contact with the arcuate portions of the inner winding **30** and being spaced from the straight portions of the inner winding **30** to leave gaps **49** between the outer and inner windings. In either case, during the injection molding of the dielectric shield **50**, the gaps **49** allow the resin to flow successfully into the space between the outer winding **40**

and the inner winding **30** and therefore fill the space with the resin without leaving any void.

FIG. 10 illustrates a modification in which a dielectric spacer **80** is utilized to create a gap between the inner winding **30** and the outer winding **40**. The dielectric spacer **80** is composed of a stopper **81** fitted to the axial end of the ferrite core **10**, and a bar **82** extending in the axial direction of the ferrite core **10** over the inner winding **30**. The outer winding **40** is wound over the bar **82** to give the gap **49** for successfully flowing the resin in between the outer and inner windings **40** and **30**. The bar **82** is formed with guide grooves **83** which receive therein the outer winding to determine the winding direction thereof.

FIG. 11 illustrates another dielectric spacer **80** which is configured to have two bars **82** extending from the stopper **81** fitted to the axial end of the ferrite core **10**. The bars **82** act to press the end of the inner winding **30** so as to successfully prevent the unwinding thereof other than a portion already being pulled out, in addition to forming the gap between the inner and outer windings.

Since the transformer of FIGS. 8 to 11 has the outer winding **40** configured to be wound so as to give the radially extending gap, it is expected that the resin can fill thoroughly in the space between the inner winding **30** and the outer winding **40** without necessitating to from the gap in the outer winding **40** itself. Thus, the outer winding **40** can be densely wound.

FIG. 12 illustrates a coil block **20** which is utilized in the transformer in accordance with the second embodiment of the present invention, and which is provided with a fixture for preventing the unwinding of the inner winding **30**. The fixture includes a cap **90** fitted to the axial end of the ferrite core **10** for prevention of the unwinding. The cap **90** is in the form of a dielectric plate having an

opening **92** which is shaped in match with the section of the ferrite core **10**, and includes projections **93** on the inner periphery of the opening **92**. As shown in FIG. 13, the projections **93** are held against the periphery of the ferrite core **10** to retain the cap **90** to the ferrite core **10**, while the cap is pressed against the inner winding **30** in an axially inward direction at its peripheral portion around the opening **92** for preventing the unwinding of the inner winding **30**. The cap **90** is shaped into a rectangular configuration in match with internal dimensions of a die for molding the dielectric shield **50**, thereby enabling the positioning of the coil block **20** within the die and therefore making it possible to surround the coil block accurately by the dielectric shield **50**. Although the figures illustrate the cap **90** mounted to the one end of the ferrite core **10**, the ferrite core **10** may be fitted at its both ends with the caps **90**. Further, as shown in FIG. 14, the cap **90** may be formed with a slit **94** in order to facilitate the engagement of the ferrite core **10** into the opening **92**. As shown in the figure, notches **96** may be formed to retain the ends of the outer winding **40** for preventing the unwinding thereof.

FIG. 15 illustrates another fixture responsible for retaining the ends of the inner winding **30**. The fixture includes a pair of caps **90A** fitted respective to the opposite axial ends of the ferrite core **10** and a coupling arm **97** interconnecting the caps. Each of the caps **90A** is pressed against the end of the inner winding to prevent the unwinding, while the coupling arm **97** is responsible for giving the gap between the inner winding **30** and the outer winding **40**, thereby assuring the resin flow during the molding of the dielectric shield **50**. The coupling arm **97** is formed with guide grooves **98** which facilitate to determine the winding direction of the outer winding **40**. The caps **90A** and the coupling arm **97** are integrally molded from a dielectric plastic resin.

FIGS. 16 to 18 illustrate various modifications of the fixture each including a pair of caps **90A** fitted respectively to the opposite ends of the ferrite core **10**. The cap **90A** is shaped into a rectangular in match with the internal dimensions of the die molding the dielectric shield, while the coupling arm **97** of the caps **90A** is formed with notches **96** for retaining the ends of the outer winding **40** or formed with metal segments **99** defining the input terminal lugs for connection with the ends of the outer winding **40**. Although not illustrated in the figures, the coupling arm may be formed with terminal lugs for the inner winding or with notches for retaining the ends of the inner winding.

FIGS. 19 and 20 illustrate an example in which the fixture is defined by a stopper **100** which is engaged into slits **12** formed at the end of the ferrite core **10**. The stopper **100** is made of an electromagnetic soft iron, the same material from which the ferrite core **10** is made, and has its legs **101** engaged into the slit **12** to be thereby fixed to the ferrite core **10** for press-holding the end of the inner winding **30**. The stopper **100** is magnetically coupled to the ferrite core **10** to bend the magnetic flux running through the ferrite core **10** to a direction perpendicular to the axis of the ferrite core, thereby increasing flux linkage between the outer winding **40** and the inner winding **30** and therefore enhancing the electrical characteristic. The stopper **100** shown in FIG. 20 is configured to have a metal terminal lug **102** welded to one of the legs **101** for connection with the inner winding **30**. The metal terminal lug **102** may project out of the dielectric shield **50** to serve itself as the terminal lug or to be utilized for connection with another terminal held by the dielectric shield **50**. The stopper is attached to each of the opposite axial ends of the ferrite core **10**, and may be made from a plastic resin. As explained hereinbefore, since the stoppers **100**

are fixed to the ferrite core with respect to the axial direction thereof, they can be kept in the position when the resin flows in the axial direction within the die molding the dielectric shield **50** for successfully restraining the unwinding of the inner winding **30**.

FIGS. 21 and 22 illustrates a coil block **20** utilized in the transformer in accordance with a third embodiment of the present invention in which a fixture **110** is disposed on the end of the ferrite core **10** to restrain the unwinding of the inner winding **30**. The fixture is composed of a retainer **111** responsible for pressing the end of the inner winding **30**, and a leg **112** extending from one end of the retainer **111**.

The inner winding **30** is wound over the leg **112** to secure the fixture **110** to the end of the ferrite core **10**, which in turn pressing the retainer **111** to the end of the inner winding **30**, thereby holding the end of the inner winding at a fixed position for preventing the unwinding thereof. The fixture **110** is applied to each of the opposite axial ends of the ferrite core **10**.

FIGS. 23 and 24 illustrate a modification of the above fixture. The fixture **110** is made of an electrically conductive material to have an integral terminal lug **114** and a leg **112** which is received in a recess **14** formed in the end of the ferrite core **10**. The leg **112** has a thickness slightly greater than the depth of the recess **14**, as shown in FIG. 24, so as to be pressed by the inner winding **30** against the periphery of the ferrite core **10** to be secured thereto. The retainer **111** has a U-shaped hook **113** for connection with one end of the inner winding **30**. The terminal lug **114** extends outwardly of the dielectric shield **50** to serve as the terminal lug. The fixture **110** is shown in FIG. 23 to have the U-shaped hook **113** of which open end oriented downward for connection with the winding

start end of the inner winding, while the fixture **110** for connection with the winding stop end is configured, as shown in FIG. 26, to have the U-shaped hook **113** of which open end oriented upward. Also for the fixture **110**, the terminal lug **114** projects outwardly of the dielectric shield to serve as the terminal lug.

FIGS. 27 to 29 illustrate modifications in which the leg **112** and the retainer **111** of the fixture **110** are molded integrally from a dielectric plastic material to carry the U-shaped hook **113** and the terminal lug **114**. By use of the dielectric material for the leg **112** and the retainer **111**, it is possible to elongate an insulation distance between the ends of the inner winding **30** as much as possible. Also, as shown in FIG. 29, the leg **112** is shaped to have an inclined surface spaced from the axis of the ferrite core **10** by a distance which becomes greater towards the center than at the axial end of the ferrite core, which is cooperative with the inner winding **30** wound thereover to bring about a wedge action for protecting the fixture **110** from being dropping out of the ferrite core **10**.

FIG. 30 illustrates a modification in which the fixture **110** includes a pair of legs **112**. In this instance, the ferrite core **10** is formed at its end with a recess **14** extending continuously from the end face to the upper and lower flat faces. The legs **112** come into engagement into the recess **14** in a fashion to bridge across the upper end lower faces by making the use of elastic resiliency given to the portion made of the plastic resin including the legs **112**. Thus, the elastic resiliency enables to secure the fixture **110** to the ferrite core **10** easily and firmly, for prevention of the unwinding of the inner winding.

FIGS. 31 to 35 illustrate modifications in which the ferrite core **10** is formed with at its axial end with notches **16** for retaining the end of the inner winding to the ferrite core for preventing the unwinding thereof. The notches **16** are

located in the arcuately curved portions in the end of the ferrite core to define flanges **18** between the notches and the axial end of the ferrite core. As shown in FIG. 32, the notch **16** has a bottom of which depth is greater towards the end face of the ferrite core **10**. Thus, the end portion of the inner winding **30** wound around the notches **16** is pressed against the flanges **18** to be retained thereby. As shown in FIG. 34, the bottom of the notch **16** may be straight as viewed from the end face of the ferrite core, or may be curved in conformity with the arcuately curved portion, as shown in FIG. 35. In the latter case, the inner winding **30** can be smoothly wound as being entrapped in the catches **16**.